Dominican Republic Environmental Protection Program (EPP)
(Water Quality)

The following is a summary of information, observations, and discussions with staff of The Nature Conservancy (TNC) and Instituto Technologica de Santo Domingo (INTEC) of potential water quality restoration projects that might be incorporated through the EPP. These recommendations are based on their potential contribution to the four themes of the EPP: (1) institutional strengthening of environmental laws, (2) conserving biodiversity, (3) promoting market-based conservation and (4) improving private sector performance. The following is only a preliminary report. I have made a variety of recommendations with the purpose that the EPP team will select certain proposals that it would like to continue to pursue and that we would direct our focus on implementing those projects. In selecting which proposed options to pursue, the EPP team should consider the expected overall contribution to the goals of the Program and how well these water quality projects may fit with other EPP projects, expected success of each proposal within the timeframe of the EPP, how well the success of each proposal may influence future activities, and the available resources for implementation (personnel, services, and materials).

Many of the suggestions are made without my sufficient knowledge or understanding of the context that each project needs to fit. In particular, the EPP team needs to consider each of these proposals as it may be affected by:

- Land ownership and land management patterns – Each of the subwatershed restoration proposals will require access and may require alteration of land use practices. How difficult will it be to get agreement from land owners and land managers to modify current practices?
- Logistics – Access to each site and access within each site, available technology and equipment will determine the type of techniques, equipment, and materials that may be used.
- Social interests – How willing are the local communities to support these projects? This can determine the long term success of any restoration.
- Institutional interests – How well will these projects align with the existing jurisdictional interests of other agencies and institutions, public and private? What is the capacity to engage these institutions as partners in these projects?
- Political interests – Will these projects require new agreements with governance at different levels, local and national? Will any of these projects require modification of previous political agreements?

The EPP team should feel free to correct, modify, and improve any of these proposals to put them in the proper context of the circumstances in the Dominican Republic and the local communities where these projects would occur. Admittedly, this report is based on observations made during my brief tour and to some extent observations and discussions with Francisco from previous travel in the DR. As a consequence, I expect there are errors in some of my interpretations that will need to be corrected. Also, many of the statements and recommendations that follow are from my personal perspective and experience in the US and should not be understood to reflect an expectation that such perspectives can be similarly applied in the DR.

WATER QUALITY MONITORING

My observations both from 2009 and 2004 visits to the DR is that there is a serious lack of coordinated water quality monitoring for most areas of the country. Certain organizations provide reasonably good monitoring and assessment of water quality but only for their specific jurisdictions (e.g. CAASD, INAPA), or for specific project-related needs (e.g. INDHIRI). As a consequence, the Dominican Republic lacks the ability to provide a comprehensive assessment of their water resources. For the DR, an area with abundant water resources and high demand for those resources, this is a serious shortcoming which can affect human health, economic health, ecological health and services, and needed information for water management decisions including prioritization of water projects that determine use, allocation, restoration, and conservation.

There does not appear to be good coordination of water management and water related decision-making. This may simply be due to my limited knowledge of water management within the DR. *As an example, when we toured the new waste treatment facility at the Jarabacoa River Club, it was noted that the requirement for the wastewater facility was made by the Tourism Ministry (presumably implementing the local Sanitation Agreement for Jarabacoa noted below), but they were still waiting for the Environment Ministry to permit the facility before it could begin operation. At the time of our visit, there were no water quality objectives established and no monitoring performed to determine quality of operation.* It has been my experience that good water management decisions require a foundation based on water quality data. This becomes the means to set the objectives for any project, prioritize where resources are spent, and determine the kind of activities required. Most importantly, water quality monitoring becomes the basis to evaluate the success of any project, to determine if objectives are attained, or if project modifications are required to assure success.

Two types of monitoring - often termed performance and response monitoring - are recommended. Performance monitoring (usually in the form of chemical and physical measures of the water) is the most familiar type of monitoring and is used to track specific contaminants in the water. Performance monitoring requires repeated testing to determine what changes are occurring in the water, at different times, places, or under special conditions, that might affect any responses that are detected.

The second type of monitoring is response monitoring (e.g. measurement of biological health or human health) which measures the cumulative condition of a water, and is a direct measure of the goals of improving human or ecological health. The most common form of response monitoring is to measure the aquatic biological community since these organisms are continuously exposed to any contaminants or other stress conditions present. For the projects under consideration in the EPP, we need to begin to collect performance data that address the potential stressors (expected contaminants), and some response measure that would be relevant to the objectives of the project. Because conserving and improving biodiversity is an overall goal of the EPP, I recommend that measures of aquatic biodiversity be collected before each project is initiated and afterwards to assess success.

Recommendations:

- Performance monitoring: Each of the projects undertaken within the EPP should have a water monitoring component. Monitoring should be determined by the objectives of each project, however, certain basic water quality measures should always be obtained. A more specific monitoring plan is included for each project below. Certain parameters (including the following field measurements: temperature, dissolved oxygen, specific conductance) should always be collected. To the extent possible, additional measures analysis for fecal coliform and total suspended solids that require laboratory are recommended. Collectively, these measures provide the most basic measures that after repeated collection over a period of time will provide a foundation of water quality information that will be useful for many purposes. It appears that most of the waters considered for restoration are affected either by bacteria contamination (from sewage) and/or high sediment loads (from erosion). Initially, the recommended frequency for sampling should be monthly, although there may be some desire to add additional samples for either high or low flow conditions or other events such as contaminant spills.
    - Because many of the project sites are distant from EPP staff, the EPP should develop local capacity to collect field data and water samples for transport to a laboratory. Our water monitoring programs in the US frequently utilize local citizens trained to conduct this work (teachers in local schools are often an excellent resource to recruit). Maine's volunteer monitoring program is described in: http://www.maine.gov/dep/blwq/docstream/vrmp/index.htm . Note that the parameters noted above are the same as Maine's 'Priority 1' parameters for our volunteer monitoring program. Josefina Vasquez (INTEC) noted to me that while working at INDHIRI she had started a "Watchman Program" that functioned similar to our volunteer monitoring programs. It might be well to look into how that program functioned and whether it is something that could be started again through the EPP. *Are there individuals who can be recruited through the EPP to train volunteers? Training could be provided by Maine staff and can also assist with evaluation of the sampling results, although it appears that INTEC and TNC may have sufficient expertise.* Development of a local corps of water monitors has great additional benefit by engaging the interest of the community. Success of any restoration project will depend on building community interest in having clean waters flow through their communities. *The EPP should invest in local educational programs to increase community awareness and interest*.

    - In additional to the five basic parameters described above, project specific monitoring may be recommended for each project area.

- Response monitoring: Development of a comprehensive monitoring plan for biological assessment may be beyond the scope and timeframe of the EPP. Nevertheless, certain projects at Arroyo de Agua Blanca and Arroyo Ancho, because they are remote sites may provide an opportunity to test basic biological assessment methods and test biological response to the restoration techniques. For these initial pilot projects, techniques using USEPA's Rapid Bioassessment Protocols should be sufficient to demonstrate biological response using stream invertebrates. (http://www.epa.gov/owow/monitoring/rbp/index.html#Table%20of%20Content) Sample collection using these methods are simple. An advantage to biological monitoring is that it does not need to be repetitive since it integrates water quality conditions over a period of time, one or two samples per year can provide adequate assessment of water quality condition, and required number of sites may be reduced (upstream and downstream of the project). Once there is some knowledge of aquatic life conditions in affected and unaffected areas we may be able to build a Biological Condition Gradient for the DR. This classifies waters into 1 of 6 potential ecological condition classes and a means to track progress.

  For the two projects recommended below (Agua Blanca, Ancho), the objectives are direct and implementation can be conducted within a short time allowing opportunity for biological response to be observed within the timeframe of the EPP. *The EPP will need to determine what resources presently exist (trained personnel, equipment, level of taxonomic expertise) in the DR to conduct this work. Training could be provided by Maine staff and can also assist with evaluation of the sampling results as needed.* Cost of biological monitoring can be relatively low depending on the level of taxonomic information desired. Most of the cost of each sample is for staff time to collect samples, travel to the sites, and taxonomic identification of the organisms. For these pilot projects, I do not recommend that taxonomy needs to go beyond the family level. Since the samples can be easily preserved, more specific identification of organisms can always be made at a later time if desired.

- Data management: The Dominican Republic needs a centralized, standardized dabtabase for water quality data and information. While each institute may prefer to conduct their own sample collection and maintain their own laboratory for their purposes, access to data between agencies and institutions should be facilitated. SEMARENA would appear to be the appropriate agency to maintain such a database and to make the data openly available between agencies and accessible to other users such as businesses and the public.
  - There are various software packages that could be used for this task. INTEC, through their information technology program, should be able to provide review of available software and to construct a database for universal use that SEMARENA could eventually be tasked to manage. *Maine staff could provide review and recommendations for this data management system if needed*.

- Incentives may need to be created to encourage different institutions to contribute their water quality data. I observed a general reluctance of the different institutions to offer their data except by special request. This creates a serious inefficiency that can be costly.

- There is no standardization of methods and no data comparison. Because data is not shared between institutions there is no means to assess methods or quality differences. Each of the laboratories that we visited had a good understanding of this problem and had quality assurance plans for their work, but laboratory evaluation was inconsistent. I do not advocate a certification program which can be costly and difficult to manage, however, a simple program of sample splits between laboratories could provide important laboratory performance information that can be shared.

- Another observation is that none of the laboratories we visited, and presumably their institutions, seemed to have much knowledge of the work of other institutions – there is little if any intercommunication. While presumably each institution works independently because their specific tasks are different, certain functions such as water monitoring and laboratory analysis are the same. A valuable task for the EPP could be to bring these institutions together in a forum where they could exchange information and data about their work. This occurs in the US both between neighboring states and within Maine in the form of annual water conferences which provides a forum for the different institutions to hear what others are doing, presentation of results of their work, and an important opportunity for staff to meet and talk to other professionals. The EPP could sponsor such conference(s) and invite individuals and organizations that are conducting water quality work in the DR. Such a conference could also be used as the forum for SEMARENA to initiate the design and implementation of a comprehensive water quality database and to recruit interested institutions to participate and contribute.

LABORATORY CAPACITY TO SUPPORT MONITORING

As part of the effort to develop water monitoring capacity, I was asked to review the capability of laboratories in Santo Domingo to provide analytical services for both basic water monitoring and for the subwatershed restoration projects. Five laboratories were reviewed (INDHIRI, CAASD, INAPA, SEMARENA, IIBI). Each review included a site visit to look at laboratory layout, available instrumentation, and to interview key personnel on experience, current workload, quality assurance practices, data management, and data availability. A brief summary of each follows:

- INDHIRI – This lab can provide most of the basic analysis that we might require. This laboratory facility is maintained for INDHIRI projects and all data is held within the institution. They can process up to 9 samples per day. Additionally, they have equipment and laboratory space provided for metals analysis (new atomic absorption unit), organic chemical analysis (new gas chromatography), and they are the only lab to offer biological (macroinvertebrate) analysis. However, while there is equipment and space there does not appear to be any trained personnel to conduct these additional analyses. They maintain a quality assurance plan and have some kind of certification through a PanAmerican institute(?).
- CAASD – This laboratory can provide most of the basic analysis that we might require. CAASD is unique in that it is the only one of the laboratories reviewed that makes its data available on their website (http://www.caasd.gov.do/) and provides a water quality index that summarizes water quality performance for the public. However, the mission of CAASD is quite separate from the kinds of projects that might be included within the EPP and their jurisdictional limit is the Santo Domingo area. While interested in our work, their appeared to be a reluctance to participate because of their jurisdictional limits. Nevertheless, they could be a useful participant if there is an effort, as noted above, to build a national database of water quality information since their data management and analysis is already open and may be more advanced than others.
- INAPA – This laboratory can provide all of the basic analyses. They are about to open a new laboratory facility with expanded space and capacity. They presently can process up to 50 samples a day and will have new automated equipment that will increase their sample processing rate, this is much greater than the other laboratories. Because the scope of their work is national, they have more experience testing a greater variety of waters. Since samples are being brought to the INAPA lab from various parts of the country it may be possible to arrange for sample transportation from our project sites. *Before we engage this facility, we should review their data quality practices in more detail.*
- SEMARENA – This laboratory has very limited analytical capacity, limited staff, and cannot perform some of the basic analysis that we would require for our projects (e.g. fecal coliform). A new laboratory facility is planned but it is unlikely it will be functioning for a year or more.

- IIBI – This is a modern well-equipped and well-staffed laboratory capable of providing all the basic analysis that we would require. Additionally they can perform trace metal and organic chemical analysis. IIBI's mission is quite different from the other laboratories since they are a private facility that provides laboratory services mostly for private business. As such, data they produce is proprietary and cannot be made available to others unless specifically requested by the client. For the purposes of our project, this arrangement could be provided so that data is entered into a publically accessible database. IIBI maintains regular quality assurance checks in cooperation with facilities in Argentina and Chile. IIBI may be used to perform certain analyses that the other laboratories are not capable of performing including trace metal analysis, pesticide, or other organic contaminants depending on the requirements of certain projects. *I have sent a separate inquiry to Hector Rosario asking for information about their ability to conduct pesticide analysis but have had no reply at this time. The EPP may wish to follow up on this inquiry*.
- INTEC – While the INTEC laboratory was not considered for our project since it is a research laboratory, I did have the opportunity to review this facility and meet with their laboratory director. While INTEC could not meet our production requirements, this laboratory might be used to provide quality assurance for any laboratory that we select for our project by analyzing a small numbers of "split" samples for comparability.

Recommendation:
I recommend that INAPA be used for basic water analysis including fecal coliform, suspended solids, DBO, DQO, nutrients, and other standard tests that may be required. They appear to have the capacity and expertise to provide required analysis. If more complex analysis are required (pesticides, metals, or other toxic substances), I recommend that we use IIBI for those analyses. I also recommend that we randomly split 5-10% of all samples and have those samples analyzed by a second laboratory for quality assurance comparison. The INTEC lab might be a suitable laboratory for this purpose since it would be a relatively small quantity of samples. The INDHIRI or CAASD laboratories would also be suitable if INAPA decides not to participate.

MICROWATERSHED RESTORATIONS - Jarabacoa area

We looked at three subwatersheds of the Rio Yaque del Norte in Jarabacoa. Each subwatershed is severely affected by urban development in the watershed, stream modification and channelization, and contamination from untreated sewage and runoff from adjacent land, roads, and buildings. As a consequence, these small watersheds are ignored and avoided by the community and their condition will continue to deteriorate. Rather than being considered part of the community and a benefit providing relief within the urban setting, they are regarded as a source of problems (waste disposal, trash, odors, flooding). Of all these impacts, the problem of untreated sewage discharge in the Jarabacoa area is the most profound. This creates a serious health condition for this area and will be a significant impediment for successful development projects in this area, especially the promotion of any water resource related tourism as described in the EPP. It is not known what health effects the community may already be experiencing from these conditions, however, the risk of direct exposure to the water by contact or indirect exposure from contaminated surfaces or aerosols from these waters is significant. Because of these unhealthful conditions, it should be a primary objective of the community to correct these conditions. The solutions for collection and treatment will require substantial engineering and construction which is outside of the scope of the EPP. A cooperative project exists within Jarabacoa (PSA-CYN, CORAASAN, GTZ, and Ayuntamiento Jarabacoa) to manage and improve sanitary conditions of the Rio Yaque del Norte, Cañada de los Gatos and Arroyo de Yerba Bueno (report: Avances y Acuerdos Sobre el Saneamiento de Jarabacoa). For the purposes of this evaluation, I will assume that implementation of this plan to correct sewage problems in Jarabacoa will continue through that cooperative agreement. Without implementation of this sanitation plan to collect and treat sewage problems, any efforts by the EPP team to make additional improvements in the three subwatersheds will be futile.

Suggested project objectives:

- Demonstrate improvement in measured water quality parameters, especially reduction of fecal coliform, increased dissolved oxygen and decreased oxygen demand (DBO5, DQO), and decreased sedimentation. Note that there is no expectation during the period of this Program that water quality standards of the DR can be attained in these waters.
- Develop local expertise and interest to measure and assess water quality improvement

Recommendations:

- Water Quality Monitoring – As explained above, there is a significant need to build a water quality monitoring program in the DR. Esmeling Genao indicated that there had been some water testing in years past but there is no measurement presently occurring. Water quality monitoring data can serve many purposes for directing treatment and ultimately the promotion of the area for development.

This Jarabacoa area would be well served by developing a community-based water monitoring plan.

- First priority for water quality monitoring should be directed at the large rivers - Rio Yaque del Norte, Rio Jimenoa, and Rio Baiguate - since these will be preferred sites for development and water resource use. Sampling should include basic field measurements (temperature, dissolved oxygen and conductivity) and a set of water samples for DBO, DQO, fecal coliform, suspended solids, and nutrients. Samples should be collected monthly. Initially, six sample locations are recommended for these large rivers. Precise locations can be determined based on location of contamination sources, access, and safety.

Rio Yaque del Norte	Upstream of Jarabacoa (rafting area)
	Jarabacoa (area of canal from Yerba Bueno)
	At confluence with Rio Jimenoa
Rio Jimenoa	Below confluence with Rio Baiguate
	At confluence with Rio Yaque del Norte
Rio Baiguate	At confluence with Rio Jimenoa

This sampling regime may be modified later, but for the first year the sampling will give us a basic knowledge of water quality condition. *Are their significant industrial contamination sources (mining or other industrial sources) upstream of the Jarabacoa area on any of these large rivers that we need to consider in our water quality assessment?*

Analisis quimica	Range RD$
Solidos suspendidos (TSS)	375-500
Coliformes fecales	580-700
Demanda bioquimica de oxigeno (DBO5)	400-500
Demanda quimica de oxigena (DQO)	500-650
Nutrientes – Fosforo total (P)	300 -750
- Nitrato (NO3)	285-650
- Amoniaco (NH3)	300-675

*Cost estimates were not provided by INAPA which is recommended as the preferred lab.

Based on some laboratory fees that we received during our laboratory visits, the estimated cost for this set of water analyses is in the range of RD$2740-4425* per sample per month (monthly cost for six sample sites RD$16,440-26,550 ; total annual cost RD$197,280-318,600). Some analysis could be eliminated to reduce costs, however it is recommended that a minimum monthly sampling frequency for TSS and fecal coliform be maintained. Hopefully, we can negotiate for a reduced price. An additional 5-10% of the laboratory costs should be provided for duplicate quality assurance samples to be analyzed.

- Water monitoring of the subwatersheds – Additional monitoring in the two subwatersheds of Arroyo Yerba Bueno and Cañada de Los Gatos would include the same parameters collected monthly. It is unclear at this time

what sampling sites to select. Until we look at the upper watersheds of these two waters in greater detail (see comments below), I recommend that you budget for at least 8 sample sites (4 per subwatershed) (annual cost: 8 sites X 12 samples X RD$2740-4425 = $263,040-424,800 + 5-10% for quality assurance analysis). This cost can be adjusted depending on the EPP budget.

- Restoration of microwatersheds: The Arroyo Yerba Bueno and Cañada de los Gatos present classical examples of a water with degrading quality as it progresses downstream from its source in surrounding hills. The most severe problem for these waters is sewage and other waste contamination from houses and businesses which occurs largely in the urbanized area. The primary objective of any restoration must be to collect and treat these wastes before they enter the arroyo. As noted above this is a public hygiene problem of high importance.

  We did not look at the upper watershed of these waters, however it appears that there is significant land clearing and agricultural use before they enter the urban area of Jarabacoa. This would be the source of a large amount of sediment that the arroyo appears to transport and deposit. This sediment load may be the more appropriate objective for the EPP to assist with restoration in the upper watershed which will reduce sediment deposition and reduce flood occurrence and damage.

- Yerba Bueno upstream of urban area – loss of riparian buffer, channelization, erodable land.

- Sewer drains and street drains entering Yerba Bueno in the urban area. Gray material downstream of drain is sewage fungus (*Sphaerotilus*) which only grows where there is a constant source of organic matter (high DBO and nutrients).


- Sediment deposition occurs during low flow periods filling channels and at constrictions at bridges increases flood frequency and intensity.

As the arroyo descends toward the urban area there appears to be a large undeveloped floodplain-wetland area with canals, some draining directly to the Yaque del Norte and some draining through the urban area. Addition investigation should be made to see how this area can be rehabilitated for water storage/release, sediment control, and flood management.

- Floodplain upstream of urban area

Recommendations for Arroyo de Yerba Bueno:

- As stated above, the most severe problem for this water is sewage and other waste contamination from houses and businesses. The primary objective of any restoration must be to collect and treat these wastes before they enter the arroyo.

- A secondary problem that could be addressed through the EPP is to improve water management in the upper watershed. It appears that riparian habitat has been affected which is causing erosion and downstream sedimentation. This area of the subwatershed was not visited. There is a need to make an extensive assessment of land use in the area upstream of the urban zone to determine what is feasible. Improvements to the riparian zone by planting trees or other permanent vegetation (reduce cultivation near the arroyo and any small tributaries) can be used to stabilize bank erosion and will also improve habitat for aquatic organisms. Better water management can be used to stabilize flows. The channel appears to have been straightened and downcut by excessive flows that prevents access of the water to its natural floodplain. *Can we obtain GIS coverage of this area that will show current land use (e.g. agriculture), roads, and other structures, and areas where the riparian zone and floodplain are still intact? Are there high resolution contour maps for this area (~1 meter contours)? This can determine potential restoration projects. It would be helpful to know how water is managed in the upper watershed – presence of drainage canals, drainage tiles, etc.*

- A number of constrictions in the stream channel, such as bridges and culverts, exist that affect the capacity to pass the flows that come down the arroyo. This problem has been managed in part by the construction of drainage canals directly to the Yaque del Norte but there is still evidence that present water management creates problems of sedimentation at low flow and flooding at high flow. This presents a very unstable condition that affects the human community, as well as the aquatic community. Improving some of these channel conditions in combination with water management noted above will improve overall quality of this water. *A survey should be made of the location and size of water passage structures (bridges, culverts) and other hardened structures (retaining walls) with the possibility that critical structures may be removed, replaced, or improved.*

Recommendations for Cañada de los Gatos

- As stated above, the most severe problem in Jarabacoa is untreated sewage and other waste contamination from houses and businesses which occurs largely in the urbanized area. The primary objective of any restoration must

be to collect and treat these wastes before they enter the arroyo. In addition to sewage contamination this water has very similar problems as Arroyo de Yerba Bueno. Many of the same actions recommended for Yerba Bueno could be applied in this subwatershed. As above, *it would be helpful to obtain GIS coverage of this area that will show current land use (e.g. agriculture), roads, and other structures? This can determine potential restoration projects. It would be helpful to know how water is managed in the upper watershed – presence of drainage canals, drainage tiles, etc. Similarly, a survey should be made of the location and size of water passage structures (bridges, culverts) with the possibility that critical structures may be removed, replaced, or improved.*

- Cañada de los Gatos. Upstream floodplain has been separated from the stream. Sediment deposition constricting flow – increasing flood frequency and intensity.

- La Vija – This is a very small arroyo that drains directly to the Jimenoa River and the entire subwatershed appears to be wholly contained within the developed community surrounding it. The problem here appears to be largely from the discharge of untreated sewage and street runoff. This would best be corrected by construction of individual or small community size septic system. It is unclear from the Sanitation Agreement whether this community area is included in that treatment plan. Protection of the good quality riparian habitat that is present upstream is recommended to assure that there is no further encroachment close to this arroyo. *An appropriate form of riparian protection should be considered by the EPP team to protect those areas that are good quality*.


- At confluence with Rio Jimenoa – reseeding and small bank stabilization work would improve condition. Upstream of La Vija community with good riparian condition.

MICROWATERSHED RESTORATION - Constanza area watersheds

Three subwatersheds were reviewed. All three watersheds are affected largely by land use practices in their watershed and do not appear to be contaminated by human sewage or contaminants from other industry or business.

Arroyo de Agua Blanca

This is a small very high gradient tributary of the Rio Grande. The watershed above Salto de Aqua Blanca branches into several smaller tributaries which come together above the falls. The area above the Salto de Agua Blanca has extensive row crop farming (potatoes, strawberries, onions, etc) on very steep slopes. The land is continuously tilled which contributes to extensive erosion. The quality of the soil observed indicated that much of the top soil had been lost leaving a coarse stony soil. Crop rotation is continuous and no fields are left uncultivated to rebuild the soil. This is not a sustainable condition even for crops such as potatoes and onions. *It would be helpful to learn more about the history of farming activity in this area – how long can fields be kept in production, have crop varieties changed as the soil has been lost, are any restoration practices used to improve soil or once a field is abandoned? It would be helpful to have a list of pesticides that are currently used in this watershed and their relative amounts*. During our visit to the site, we looked at one of these tributary waters which showed evidence that considerable stormwater and eroded soil enters the arroyo during storms, carrying with it fertilizer and pesticides. It was reported that the arroyo has very poor aquatic life which would be attributed to these conditions. The tributary that we looked at still had reasonably good riparian habitat along its banks thus a primary restoration goal should be to reduce direct stormwater runoff from the farm fields. It is assumed that this tributary is representative of the other waters that lead to the Salto de Aqua Blanca. *It will be helpful in developing any project in this area to have high resolution GIS coverage to look at land use relative to slope and distance from waters.*

- Large portions of this subwatershed are in continuous cultivation on steep slopes. Note severe erosion in foreground and left portion of photo.

- Excess water from the fields is directed downslope directly to Arroyo de Aqua Blanca creating soil erosion and high flows that cause channel erosion. Runoff water in drainages like these needs to be spread across grassed land to allow infiltration into the soil, or directed into detention ponds for sediment removal before discharge.

Suggested project goals:

- Decrease erosion and stream sedimentation
- Decrease nutrient and pesticide contamination
- Improve natural flow
- Increase aquatic biodiversity

Recommendations: There are a number of approaches that could be used separately or in combination to improve water quality.

- Taking these lands out of agricultural production, especially those areas on the steepest slopes, and replanting to native forest vegetation would be the most effective means to restore water quality. I will assume that this is an unlikely option and would be very disruptive to the community. It might be possible to identify individual fields that either because of severe erosion or because of reduced production could be selected for restoration. *TNC could provide recommendations for reforestation of these sites in cooperation with SEMARENA (forest resources).* It is unclear to me how farming and the designation of this area within a "national park" are compatible management policies.

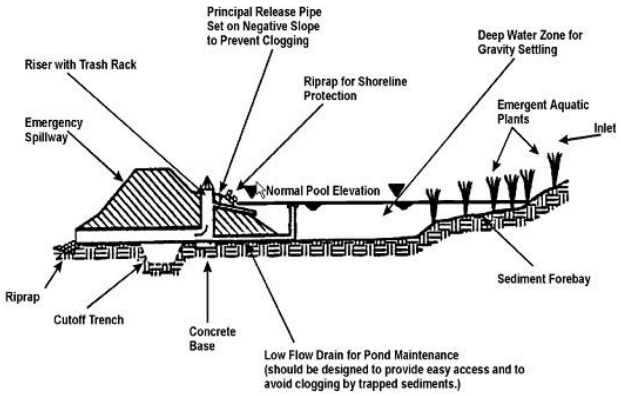
- An alternative to replanting with native forest vegetation would be to change to an agriculture crop that does not require tillage. Perennial crops, such as fruit or nut trees, berries, etc., can be grown with little or no tillage once the crop and associated ground cover is established. These plants develop deep soil-retaining root systems. *The EPP team would need to obtain assistance from a local agronomist to identify alternative crops that would be suitable for the local soils, climate, and available markets*.

- Considerable improvement can also be made by limiting the use of fertilizers and pesticides on the land. I am assuming there is no nutrient or pest management plan. By assisting the farmers by testing the soil for nutrients and to use fertilizer only to bring the soil up to recommended fertility levels will reduce the loss of excess fertilizer to the arroyo. Likewise a pesticide use plan should specify treatments only as the pests (fungus, weeds or insects) occur. This would require teaching the farmers how to inspect their crops for the presence of pests. The implementation for both a nutrient management plan and a pest management plan will reduce the use of these chemicals and will be a direct cost saving to the farmers. The practice that we observed of spreading pesticides by backpack spray is a preferred method since it will limit chemical drift, however, the handling and mixing of the chemicals appeared to be haphazard, subject to spills, and a direct hazard to the farm workers as well as the water. Improved education for farm workers would benefit both the workers and the watershed, and the more efficient use of chemicals will provide a cost reduction to the farmers.

- Engineered restoration techniques. Because of the steep slopes at this site, it is expected that even with implementation of the recommendations above, there will still be significant erosion and sediment runoff from this site into Arroyo de Aqua Blanca. Several techniques are available that would be relatively inexpensive and require limited maintenance that could be performed by the local workers. *The EPP may find it worthwhile to review Maine's Erosion and Sediment Control Best Management Practices (BMPs) for ideas. In particular the sections on water conveyance, water detention, and roads may be of most interest.* http://www.maine.gov/dep/blwq/docstand/escbmps/ .
  Keep in mind that these practices are designed for conditions that don't occur in the DR (e.g. frozen ground, snow cover) but they are still conceptually appropriate and may actually be more effectively used in the DR because you don't have these extreme cold weather conditions. Most of my examples below are from our experience using these techniques. The general concept is that rather than collecting runoff water for immediate diversion to a stream which has been the usual practice, the water is diverted over land or retained in pond structures for infiltration and slow release from the watershed. This provides a means to filter sediment, which is what most of the nutrients and pesticides are attached to, as well as reduce both flood flows and drought flow events in the stream. *As with all the proposed project sites, it will be helpful if the EPP could obtain current GIS coverage of topography, land use, and good contour mapping of this subwatershed area upstream of Salto Agua Blanca.*

  As examples, detention ponds are sediment traps designed to capture runoff water, hold it for a period of time to allow sediment to settle, and then discharge to the arroyo. The following provides a general description of detention ponds ("wet pond").

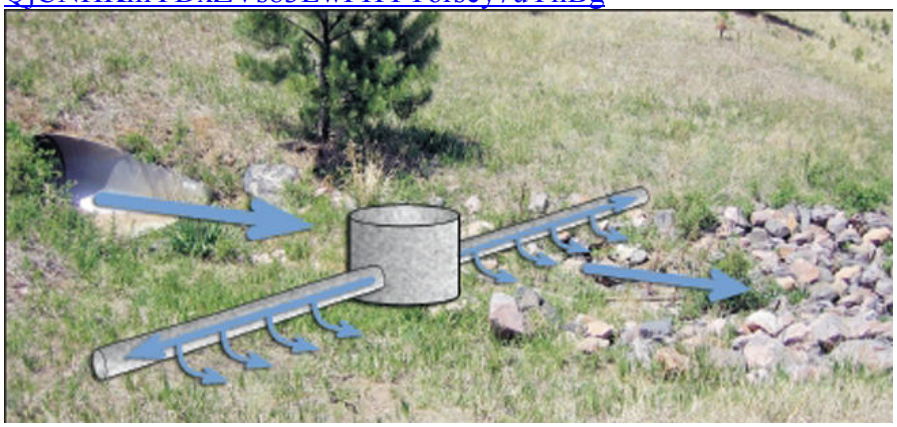
See further explanation in:
http://en.wikipedia.org/wiki/Detention_basin#Functions_and_design



Detention ponds are located downgrade from the fields and can be built in series or as single large detention ponds at the base of a field. During dry periods, water in the ponds can be pumped uphill (require provision of pumps) and used as a source of irrigation water to reduce the demand place on the natural flow in the arroyo. These ponds will require occasional maintenance to remove the accumulated sediment for reapplication to the fields. Consideration may also need to be given for mosquito control in the ponds if this is a local problem.

Level spreaders are simple designs that use natural or graded grassed land to spread flows and filter particles from the water. An example is shown below but there are many designs depending on the specific site conditions. See references below:
http://www.bae.ncsu.edu/stormwater/PublicationFiles/LevelSpreaders2006.pdf

http://docs.google.com/gview?a=v&q=cache:nET2fBT5VPoJ:www.bae.ncsu.edu/cont_ed/main/handouts/lsworksheet.pdf+level+spreader&hl=en&gl=us&sig=AFQjCNHKmYDxZVs83LwPHYTorsey7uYhBg



The very steep terrain in this area may limit the available sites where level spreaders can be used. Consideration will need to be given to equipment and materials that will be needed for construction of these devices. *As discussed with José Contreras, INTEC, through their hydrology program and engineering program, may be able to provide designs for these water management structures as part of practical exercises for the students*.

- Water monitoring: Because of the remote character of the site, regular water monitoring may be difficult. Water sampling may have to be limited to occasions when members of the EPP team are working in the area since it will otherwise be difficult to arrange transport of samples back to the lab. For this project, I would recommend that we only collect total suspended solids and nutrients (fosforo, nitrate, amoniaco). Laboratory cost would be RD$1260-2575 per sample. It is unknown how may sampling locations we would establish for this subwatershed and as noted above the frequency of sampling may be limited to occasions when someone from the EPP team is working in that area unless there are other arrangements for sample transport. My expectation is that these waters are not significantly contaminated with fecal coliform or oxygen demanding wastes (DBO, DQO) so we would only need a few measurements to confirm that. Pesticide monitoring may be important for this project area because of the intense agriculture. Direct measurement in water is not a good means to detect pesticides. We have developed devices that can be left in the water that collect and concentrate trace amounts of pesticides. These methods are still experimental and somewhat costly unless we can get a lab like IIBI interested in providing analysis without having to ship the samples out of the country. We do not need to decide on pesticide monitoring just yet and I will continue to review some possible approaches to that analysis that would be appropriate for the circumstances.

  This would be a good site to use for biological monitoring since that does not require as much repeated sampling. Antonio provided an estimate that the watershed above Salto de Aqua Blanca is about 10 km^2, with about 6 km^2 above the agricultural area. If there is still an area of intact forested watershed above the cultivated area, we can use that area to collect background biological data about what the water quality is before it is affected by the agricultural lands and what the expected biological condition should be. Access to this upper portion of the watershed is unknown and difficulty accessing the site may limit the frequency and type of sampling that occurs. Information from the biological monitoring, such as any detection of a toxic effect in the arroyo, may indicate whether we conduct testing for pesticides. The biological information can also provide a good measure of restoration improvements.

Arroyo Ancho

Arroyo Ancho is a small tributary of Rio Baiguate with terrain that is steep and eroding. Agriculture and human habitation in this subwatershed is low compared to other waters that were visited. It appears that large portions of the watershed may have been in cultivation or used for livestock grazing are no longer intensively used. The road which follows the arroyo is in poor condition and is a significant source of the sediment in the water. As a consequence, this arroyo carries a significant sediment load, increasing as it travels from headwaters to its confluence with the Rio Baiguate. We could not follow the road to its end so it is unknown if there is significant agriculture in the upper part of the watershed or other land use activities that are affecting water quality. It is also unknown how much vehicle use this road has. The riparian condition of this small arroyo is still relatively good. This arroyo has very good prospects for restoration. If the greater objective of this project is to improve water quality (reduce sediment) in Rio Baiguate, Arroyo Ancho is an excellent site for a demonstration of restoration potential. *The EPP team may also want to look upstream at other tributaries, such as Arroyo de la Pita, and the Rio Baiguate headwaters for future restoration projects. The topographic map indicates similar land conditions and roads that are contributing to the large sediment load in the Rio Baiguate. As with all the proposed project sites, it will be helpful if the EPP could obtain current GIS coverage of topography and land use.*

Suggested project goals:

- Decrease erosion and stream sedimentation in Arroyo Ancho
- Improve stability of the road
- Improve quality of forested watershed
- Increase aquatic biodiversity

➢ Incomplete revegetation in the upper watershed.


- Eroded conditions along the road. Side slopes, drainage ditches and road surface have severe erosion. Note good riparian vegetation next to the arroyo.

Recommendations for Arroyo Ancho

- Maintenance and improvement of the road would decrease sediment load considerably. The road has few culverts or ditches where water can be diverted away from both the road and the arroyo. The road surface is eroding as well and side ditch and banks. Reconstruction of the road drainage should be a primary objective. Water should be diverted onto vegetated land where practical or into retention ponds where that is not practical (see description in section on Aqua Blanca and potential restoration methods described in Maine's Erosion and Sediment Control Best Management Practices (BMPs). *This may be a project where INTEC can bring its engineering expertise to redesign the road drainage.* Side ditches should be vegetated or lined to reduce erosion.. Side slope angle should be reduced where possible and vegetated to reduce landsliding as seen in the photo. *EPP team will need to consult with experts on the appropriate kinds of ground vegetation to use that will hold the soil.*

- Reforestation of watershed. Significant portions of this subwatershed do not appear to be in agricultural use and are unforested or underforested. There is good opportunity to accelerate regrowth of the forest through planting. In addition to reducing soil erosion, an improved forest will improve rainfall capture, retention, and release which will improve the hydrology of this watershed. *TNC should be able to provide expertise for a reforestation plan for these sites (would there be opportunity to incorporate carbon credits as part of the reforestation project?)*

- Water monitoring: Because of the remote character of the site, regular water monitoring may be difficult. Water sampling may have to be limited to occasions when members of the EPP team are working in the area since it will otherwise be difficult to arrange transport of samples back to the lab. Similar to Arroyo de Agua Blanca, we can reduce the number of parameters that we regularly measure at this site to suspended solids and nutrients. Laboratory cost would be RD$1260-2575 per sample. The number of sampling locations would probably be as few as

three or four and as noted above the frequency of sampling may be limited to occasions when someone from the EPP team is working in that area unless there are other arrangements for sample transport. My expectation is that these waters are not significantly contaminated with fecal coliform or oxygen demanding wastes (DBO, DQO) so we would only need a few measurements to confirm. I do not expect effects from pesticides since agriculture activity appears to be low so we would not analyze for those substances.

This would be a good site to use for biological monitoring since that does not require as much repeated sampling. If there is still an area of intact watershed above the affected area, we can use that area to collect background biological data about what the expected biological condition should be before it is affected by any agricultural use or the road. Access to this upper portion of the watershed is unknown and difficulty accessing the site may limit the frequency and type of sampling that occurs. The biological information can also provide a good measure of restoration improvements.

Rio Tireo (Cruz de Cuaba area)

Rio Tireo is a very large watershed with intensive agriculture. Antonio estimated that the watershed is about 40 km^2 with 95% or more of the area in cultivation, much of this area is on steep slopes. Because of the large size of the drainage and the extent of landscape-scale erosion from agriculture, this would not be a good demonstration project site for the EPP since there would be little expectation of significant measurable water quality improvement within the resources and timeframe of this program.

- Severe erosion resulting in a very concentrated stream sediment load.